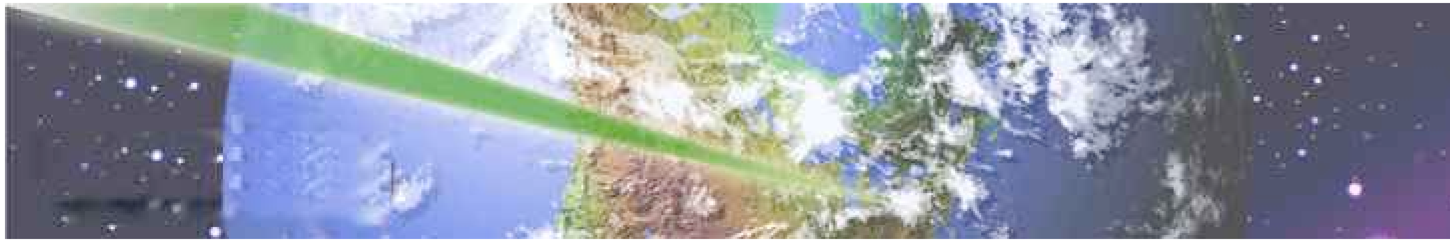

Satellite Laser Ranging Concept Review

Experience Incorporated into the Replacement System

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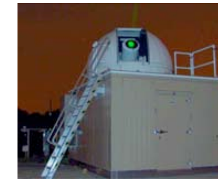
July 26, 2004

Experience Incorporated into the Replacement System

- Why replace the existing Goddard MOBLAS Network?
- Are we at the end of MOBLAS Network upgrade path?
- Current NASA SLR Challenge: Do more with less
- Existing SLR Network hazards
- Lessons learned in 25 years SLR
- Future Satellite Laser Ranging system capabilities
- Innovative hardware developed, key instrumentation
- MOBLAS/Next generation SLR comparison
- Where next generation SLR must be headed
- Technical Risks and Issues addressed by the SLR2000 prototype testbed

Why Replace the Existing SLR Network?



- **Late 70's technology** (7-10 cm RMS)
  - Nanosecond Q-switched lasers
  - Nanosecond response receivers
- **Upgrade path has been exhausted**
  - Laser, receiver electronics replaced
  - Telescope, mount, servo electronics 25+ years old
- **Costly to operate/maintain**
  - Custom built electronics
  - Spare parts unobtainable
- **Operator hazards still exist**
  - Electrical, chemical, ocular and toxic fume hazards are present
- **More tracking demands made**
- **SLR techniques need to be updated**
  - 24/7 tracking, new techniques, instrumentation, more computing power required

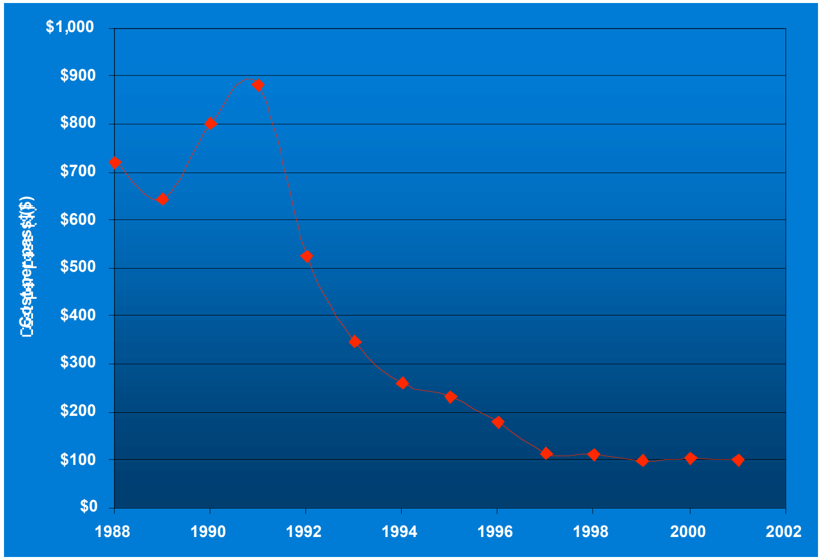
We are at the end of MOBLAS SLR Upgrade Path

- **Network deployed late 70's**
- **Ranging hardware upgrades:**
  - Q-switched lasers replaced early 80's (1 to 5 Hz upgrade)
  - Photomultiplier tube (PMT), Timing Discriminator (CFD), and Time Interval Unit upgraded in the mid-80's: (1-2 cm RMS)
- **One CPU upgrade to Pentium**
- **RADAR and GPS epoch timing systems installed in 90's**
- **Four man crew reduced to single person operations in 90's**
- **MOBLAS systems "MAXed" out in data quality and quantity**

Current NASA SLR Challenge

Do more with less: Track more satellites with less funding...

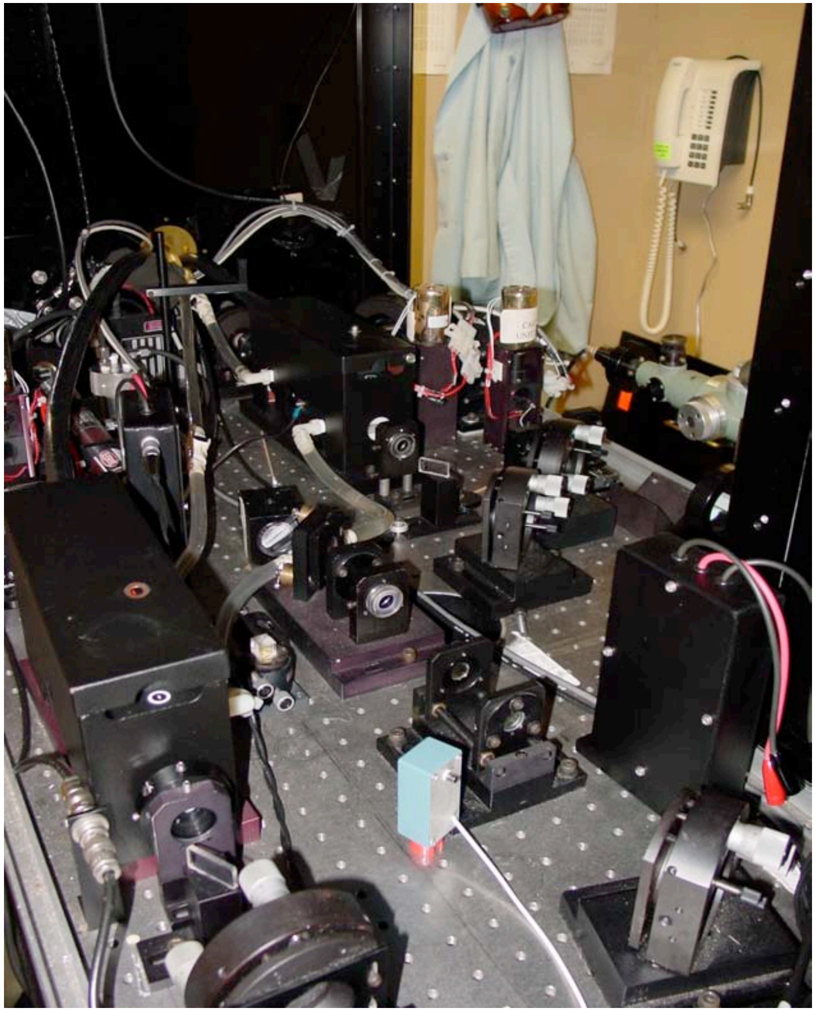
SLR Cost Per Pass Down



- **Current NASA Systems have improved data quality and quantity over last 10 years.**
  - Subsystem upgrades result in sub-centimeter performance
  - Decreased operating costs through system improvements, automation, and crew cross-training
  - More satellite missions are being supported

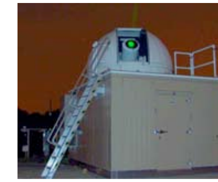
Performance limits have been reached with existing systems

SLR Network Hazards Still Exist



- **Electrical: Lethal HV capacitor banks for flash lamp pumping of laser rods**
- **Chemical: Flowing dye cell for Q-switching laser, gloves required (carcinogen)**
- **Fumes: Vented hood and respirator required**
- **Ocular: 100mJoules/pulse, safety goggles, mount safety observer required or radar**
- **Single man operation continues...**

What we have learned in 25 years of SLR



- Data quality improves with shorter laser pulses and with higher bandwidth receivers, and data quantity goes up with system repetition rate
- Upgrade paths for new technologies and instrumentation must be open for future development
- SLR timing instrumentation errors need to be identified, quantified, and minimized
- 24/7 operation is routine with adequate satellite predicts, appropriate receiver and electronics gating, FOV, BPF, etc.
- More real time computing power is always an advantage
- Multi-photoelectron returns are not required for accurate ranging: Use photons efficiently (i.e. single photon detection)
- Large telescopes with high power lasers are no longer required
- Laser electrical, chemical, and ocular hazards can be retired
- Partnering with the international SLR community improves tracking coverage and encourages new ideas and technologies at no additional cost

Future NASA SLR Systems will...

- Fully automated, no operator
- Centimeter ranging accuracy
- Track CCR equipped satellites to 20,000 km altitude, 24/7 operation
- No ocular, chemical, or electrical hazards
- Small, compact, self-monitoring, low maintenance, increased reliability
- Automated satellite scheduling
- Data processing and delivery via the internet
- Lower replication/operating costs
- Use as many COTS items as possible

Innovative Hardware Used in the Next Generation SLR System

- Multi-kHz diode pumped Nd:YAG microchip laser
- New quadrant microchannel plate (MCP) PMT
- Closed loop tracking with quadrant timing detector
- Full aperture transmit and receive telescope use (eyesafe)
- Passive 2 kHz transmit/receive switch
- Risley prism point ahead of transmitted beam
- 2 kHz Event Timer/Range Gate Generator
- All sky thermal IR camera monitors sky conditions
- Signal recognition algorithms developed to pull the signal from the noise

Autonomous SLR Weather Station

Young 05103V
Wind Speed
Tracker & Monitor

Measures
- Wind Speed
- Wind Direction

TrueTime XL-DC
Time and Frequency Receiver
GPS Antenna
- Receives GPS Timing Information

Paroscientific MET3
Meteorological
Measurement System

Measures
- Pressure
- Temperature
- Humidity

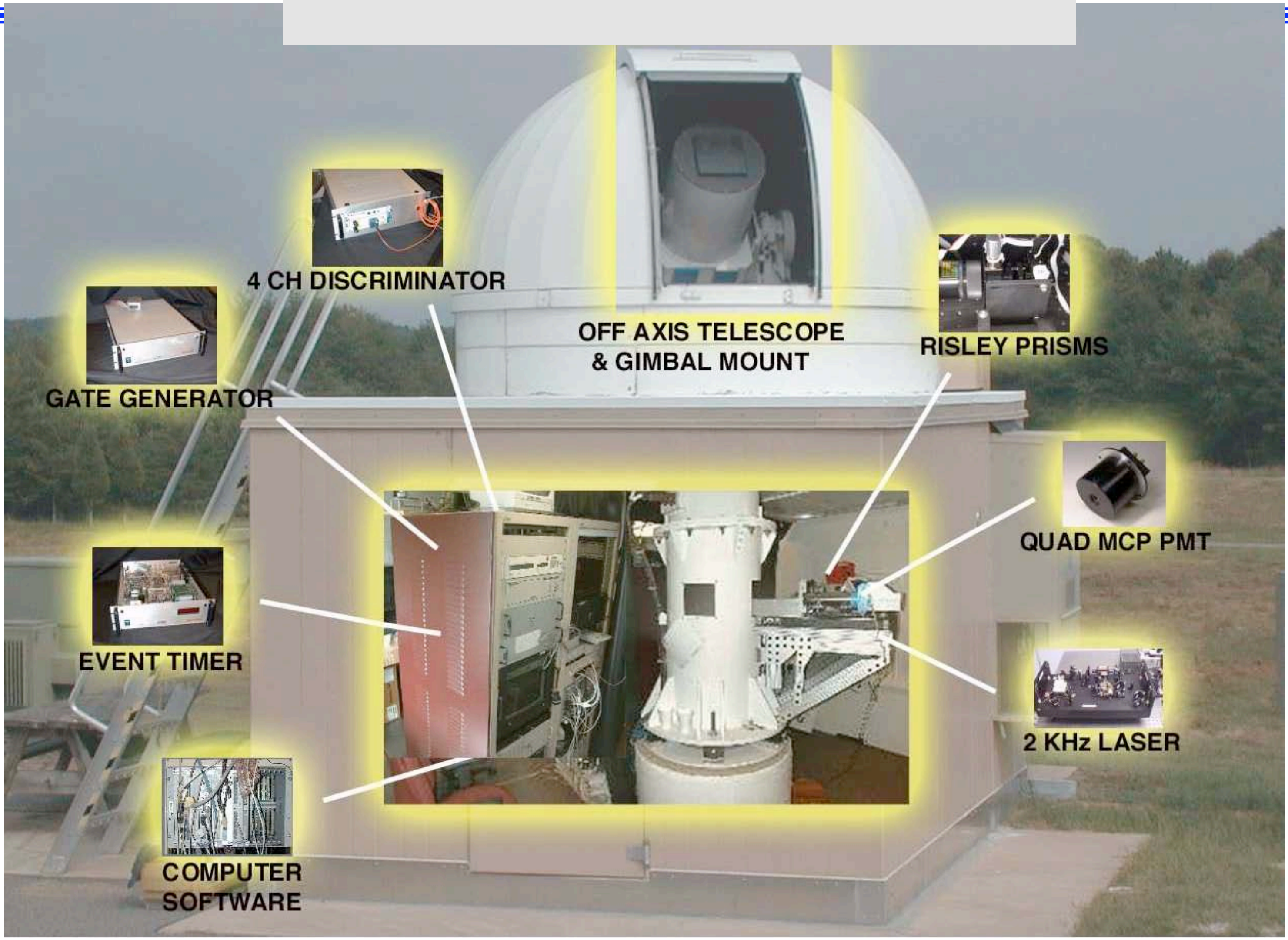
Pelco MC3651H-2
Camera
- Remote System Monitoring
- System Security
- System Troubleshooting

All Sky
Camera
- Sky Visibility
- Cloud Cover

Vaisala FD12P
Weather Sensor

Measures
- Visibility
- Precipitation
- Precipitation Type
- Precipitation Rate

Next Generation SLR Key Instrumentation



MOBLAS/SLR2000 Comparison

	MOBLAS	**SLR2000**
Transmitted Energy	100 mJoules	130 uJoules
Repetition Rate	5 Hz	2000 Hz
Average Power	.5 Watts	.26 Watts
Accuracy	~1 cm RMS	~1 cm RMS
Av. return level	20-1000 pe's	<1 pe
Measurements/sec	5	few ~ 1000

Next Generation SLR will Retire Tall Poles

- **Human operator must be replaced**
  - Smart weather instrumentation to access tracking conditions
  - Automated console operations for system pointing and timing calibrations
  - Automated closed loop satellite tracking algorithms
  - Automated scheduling, flow and analysis of data products
- **Health and safety issues have been addressed**
  - Electrical, chemical, and fume hazards will be retired
  - Eyesafe laser tracking operations
- **New key instrumentation developed...**
  - Low cost, low maintenance, high reliability laser transmitter
  - Single photon detection quadrant receiver for time of flight measurement
  - Innovative passive Transmit/Receive switch
  - High speed Event Timer and Range Gate Generator

Technical Risks and Unresolved Issues Addressed by the SLR2000

- **Adequate laser energy/lifetime not yet demonstrated**
  - Although recent developments in laser design should retire this issue
- **Quadrant MCP photomultiplier tube lifetime unknown**
  - Current MCP tubes have up to 15 years operation in MOBLAS systems
  - Blanking of receive PMT (when laser fires) complicates observations
- **Closed loop quadrant tracking not yet demonstrated**
  - Risley point ahead optics are in place but not yet tested
  - Control algorithms written but untested
- **System automation/reliability testing is a lengthy process**
- **Subsystem upgrade path needs consideration**
  - System layout and configuration is upgrade friendly
- **SLR2000 testbed completion/success needed for risk mitigation**
  - Demonstration of key subsystem techniques minimizes new engineering costs of proposing contractors
  - Knowledge of all subsystems operations and limitations are required for intelligent proposal selection